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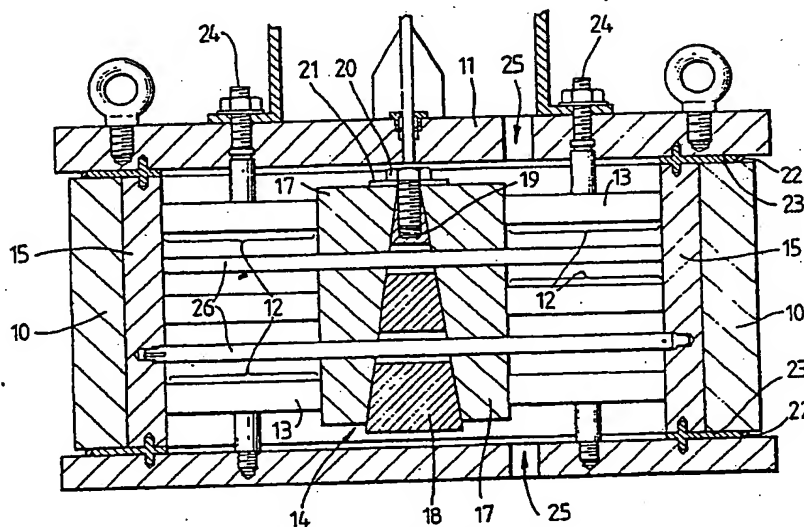
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(54) Flextensional transducers.

(57) A flextensional transducer comprising a shell defining a cavity and drive means located in the cavity and adapted to cause the shell to flex and further comprising a Helmholtz resonator for forming a hydrostatic pressure link and a low frequency acoustic link with the medium in which the flextensional transducer is located.

*Fig. 2.*



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### Flextensional Transducer

The present invention relates to a flextensional transducer which is adapted for use at greater depths than known flextensional transducers.

Flextensional transducers are electro-mechanical transducers adapted to generate (or detect) sound in a fluid medium. An example of a known form of flextensional transducer is disclosed in European Patent Application No. 0215657A in which an elliptical cylindrical shell and end plates define a cavity containing a piezoelectric ceramic drive stack for causing the shell to extend along the major axis of the ellipse thereby causing the sides of the shell to flex.

The yield strength of piezoceramics while in tension is relatively low therefore it is important that the drive stack is maintained in compression otherwise fractures could occur during use. This limits the depth to which the flextensional transducer can be used since at greater depths the higher hydrostatic pressure tends to compress the sides of the shell thereby elongating the major axis of the ellipse and reducing the compressive force on the drive stack. Most flextensional transducers produced to date have inherent depth capabilities of only approximately 100 metres.

Pressure compensation arrangements for flextensional transducers have been suggested and one such arrangement is disclosed in EP0215657A in which an adjustable wedge assembly is used to prestress the drive stack and to compensate for pressure changes. Another example of a pressure compensation arrangement for a flextensional transducer is disclosed in Canadian Patent No. 1171950 in which an annular resonator is provided with a bladder in communication with the surrounding medium.

Known pressure compensation arrangements complicate the construction of the flextensional transducer.

According to the present invention we provide a flextensional transducer comprising a shell defining a cavity and drive means located in the cavity and adapted to cause the shell to flex and further comprising a Helmholtz resonator for forming a hydrostatic pressure link and a low frequency acoustic link with the medium in which the flextensional transducer is located.

Advantageously, a flextensional transducer according to the present invention is insensitive to ambient pressure and consequently can operate at effectively unlimited depths.

Preferably, the resonance frequency of the Helmholtz is substantially different from the resonance frequency of the cavity. In the embodiment to be described the resonance frequency of the Helmholtz resonator is approximately one octave lower than the resonator frequency of the cavity.

A further advantage is that the correct spacing of the cavity and Helmholtz resonance frequencies gives the flextensional transducer an extended low frequency performance.

In the embodiment to be described the shell is an elliptical cylinder and there are two plates abutting the ends of the shell and the Helmholtz resonator comprises an orifice formed in a plate abutting an end of the shell. The flextensional transducer may comprise a Helmholtz resonator with a double orifice - one in each end plate.

In use, the cavity may be filled with seawater.

This has several advantages:

it reduces the static weight as the transducer can free-flood and empty via the orifice during deployment;

it means that mechanical seals no longer become critical items of design;

it produces the simplest possible transducer.

Alternatively, in use the cavity may be filled with an elastomer eg polyurethane. An elastomer is likely to be relatively dense and stiff and will thus increase the Helmholtz resonance and may reduce efficiency at the flextensional resonance. However, it would produce a very rugged design.

As a further alternative, in use the cavity may be filled with oil, use of oil would ease the problems of operating at very high voltages, and a diaphragm over the orifice could contain the oil, but differential thermal expansion may cause both mechanical and acoustic problems.

In all cases, the drive assemblies need only be prestressed for amplitude plus a margin for safety. Stressing for any depth of operation becomes irrelevant once the cavity has flooded.

A particular embodiment of the present invention will now be described, by way of example, with reference to the accompanying drawings in which:

Figure 1 is a perspective view of a flextensional transducer according to the present invention;

Figure 2 is a vertical section view of the flextensional transducer of Figure 1;

Figure 3 is a horizontal section view of the flextensional transducer of Figure 1.

Figure 4 is a schematic representation of the frequency response of a flextensional transducer according to the present invention;

Referring to the drawings, there is illustrated a flextensional transducer for use underwater for emitting high power, low frequency acoustic energy.

The transducer comprises a thick-walled ellip-

tical cylindrical shell 10 of aluminium sealingly and slidably supported between two end plates 11. A drive arrangement extends along the major axial plane of the shell 10 and comprises six stacks 12 of piezoelectric ceramic cells 13 arranged in three opposed pairs located each side of a central wedge assembly 14. The stacks 12 act on the opposed wall sections of the shell element via respective D-section bars 15. The cells may be made, for example, of lead zirconate titanate, and connected in parallel to receive an electrical energising signal. When energised, the stacks vibrate axially and thus induce the shell element to vibrate at the same frequency. Instead of being made from piezoelectric material, stacks 12 may be formed of magnetostrictive material.

The central wedge assembly comprises two outer wedge portions 17 each connected to one end of the respective drive elements 13 and an inner tapered portion 18. The thin end of the tapered portion 18 includes a threaded bore 19 in which is engaged a bolt 20 which, together with washer 21, maintains the outer wedge portions 16 and the tapered portion 17 in predetermined relative positions and thus maintains on the transducer as a whole a predetermined compressive load. A seal ring 22 and a spacer plate 23 are slidably located between each end face of the shell 10 and associated end plate 11 to allow the shell to vibrate freely with respect to the end plates whilst preventing ingress of fluid. The end plates 11 are held in place by means of two tensile bolts 24 passing therebetween.

Both of the end plates 11 contain an orifice 25. In use, the orifices react with the cavity to form a Helmholtz resonator. Hence, in use the compliance of the cavity defined by the shell 10 and the end plates 11 reacts with the fluid masses in the orifices 25 to resonate. The dimensions of each orifice 25 control the respective Helmholtz resonance for a given size of cavity.

Ideally, the Helmholtz resonance is well-spaced from the cavity resonance. For example, in an 800Hz flextensional transducer the Helmholtz resonance may be set one octave lower ie at 400 Hz (implying a wavelength of 3.75 metres). Typically the orifices 25 are 10mm in diameter. An orifice so tiny compared with its wavelength will have very low radiation resistance and should therefore contribute very little to the transducer output. The Helmholtz resonance will have a very high Q and it may be necessary to damp the resonance to avoid excessive excursions of the shell if the resonance is accidentally excited.

Damping may be achieved acoustically by placing damping material, such as rubber, in the cavity. Alternatively, damping may be achieved by a feedback arrangement in which a hydrophone in

the cavity provides a signal to control the drive voltage of the drive stacks 12.

Correct spacing of the cavity resonance and the Helmholtz resonance give the flextensional transducer an extended low frequency performance. Figure 4 shows the response of a flextensional transducer including a Helmholtz resonator (full line) contrasted with that of a known flextensional transducer (dotted line).

The drive stacks 12 are potted in a electrically insulating elastomer such as polyurathane (as indicated by shading in Figures 2 and 3).

The cavity may contain a plurality of compliant tubes 26 for helping to lower the Helmholtz resonance. The tubes are suitable for immersion to great depth. The tubes 26 are elliptical in cross-section and are thin-walled metallic tubes having sealed ends and filled with air. Other forms of compliant tubes may also be used for this purpose or differently shaped compliant articles may also be suitable.

In use, the transducer is lowered to the required depth in seawater and a driving signal at the required frequency is supplied to the drive elements via cable 27, to cause vibration of the shell element. The two orifices 25 permit the cavity of the flextensional transducer to flood freely with seawater.

Consequently, irrespective of the depth of the flextensional transducer, the cavity is at the same hydrostatic pressure as the ambient sea water so that the flextensional transducer is insensitive to depth changes.

Some loss of efficiency at the flextensional resonance must be expected as the shell will now have to move fluid on its inside surface as well as its outside, but its radiation characteristics should not be greatly affected. This embodiment of flextensional transducer operates analogously in some respects to a bass-reflex cabinet type of loudspeaker. At low frequencies and "DC" acoustic pressures, radiation from inside the cavity of the flextensional transducer which is out of phase with radiation from the exterior of the shell 10, radiates through the orifices 25, still out of phase, giving a poor response. At the Helmholtz resonance of the cavity plus the orifices 25 a phase change occurs and, above resonance, the internal radiation emerges from the orifices 25, if at all, phase reversed and in phase with the external radiation.

In alternative embodiments to the one described above there may be only a single orifice in the flextensional transducer to form a single Helmholtz resonator. As mentioned previously, the cavity may be filled with substances other than seawater, such as oil or an elastomer.

## Claims

1) A flextensional transducer comprising a shell defining a cavity and drive means located in the cavity and adapted to cause the shell to flex and further comprising a Helmholtz resonator for forming a hydrostatic pressure link and a low frequency acoustic link with the medium in which the flextensional transducer is located.

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2) A flextensional transducer according to claim 1 wherein the resonance frequency of the Helmholtz resonator is substantially different from the resonance frequency of the cavity.

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3) A flextensional transducer to claim 2 wherein the resonance frequency of the Helmholtz resonator is approximately one octave lower than the resonator frequency of the cavity.

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4) A flextensional transducer according to any preceding claim wherein the shell is an elliptical cylinder and there are two plates abutting the ends of the shell and the Helmholtz resonator comprises an orifice formed in a plate abutting an end of the shell.

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5) A flextensional transducer according to any preceding claim comprising an orifice in each end plate, to form a Helmholtz resonator.

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6) A flextensional transducer according to any preceding claim wherein the Helmholtz resonator comprises an orifice which is approximately 10mm long.

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7) A flextensional transducer according to any preceding claim wherein the cavity is adapted to be filled with seawater in use.

8) A flextensional transducer according to any one of claims 1 to 6 wherein the cavity is adapted to be filled with oil in use.

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9) A flextensional transducer according to any one of claims 1 to 6 wherein the cavity is filled with an elastomer.

10) A flextensional transducer according to any preceding claim wherein the drive means is potted in an electrically insulating material.

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11) A flextensional transducer according to any preceding claim comprising one or more compliant tubes in the cavity.

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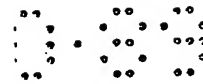


Fig. 1.

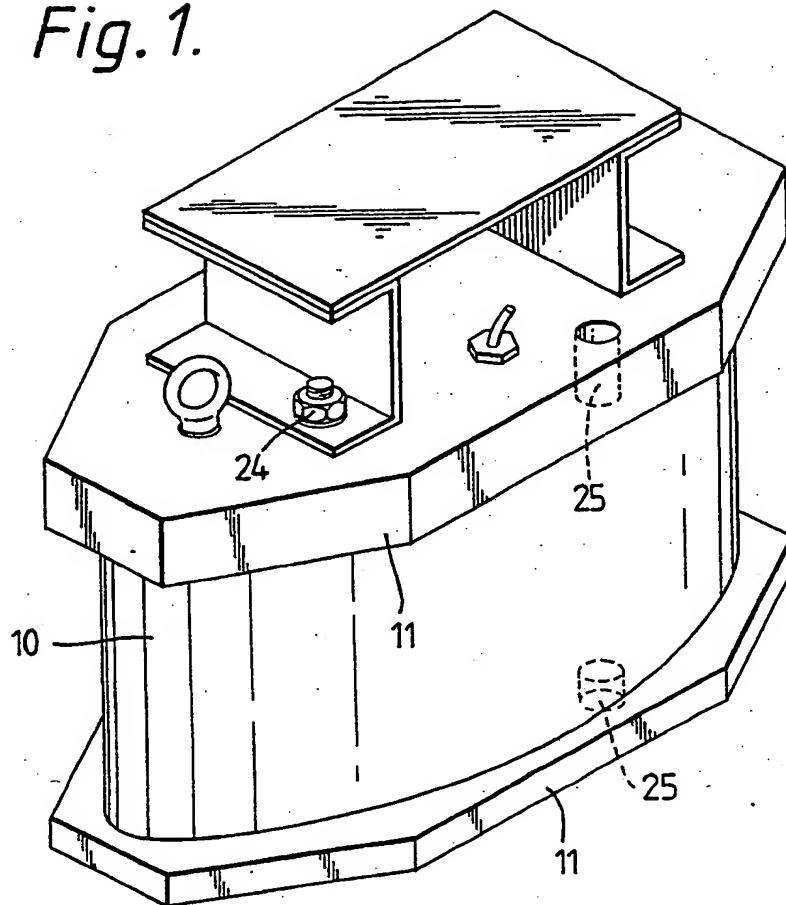
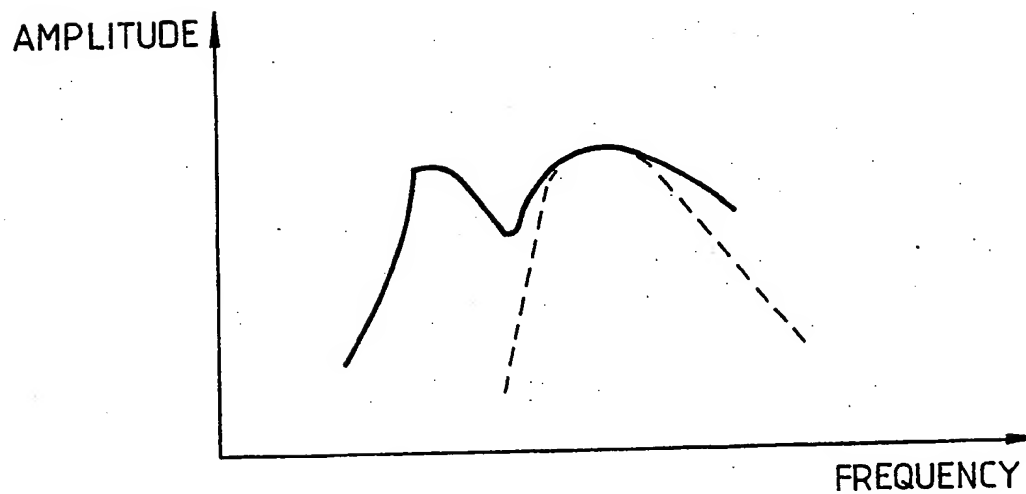


Fig. 4.



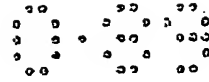


Fig. 2.

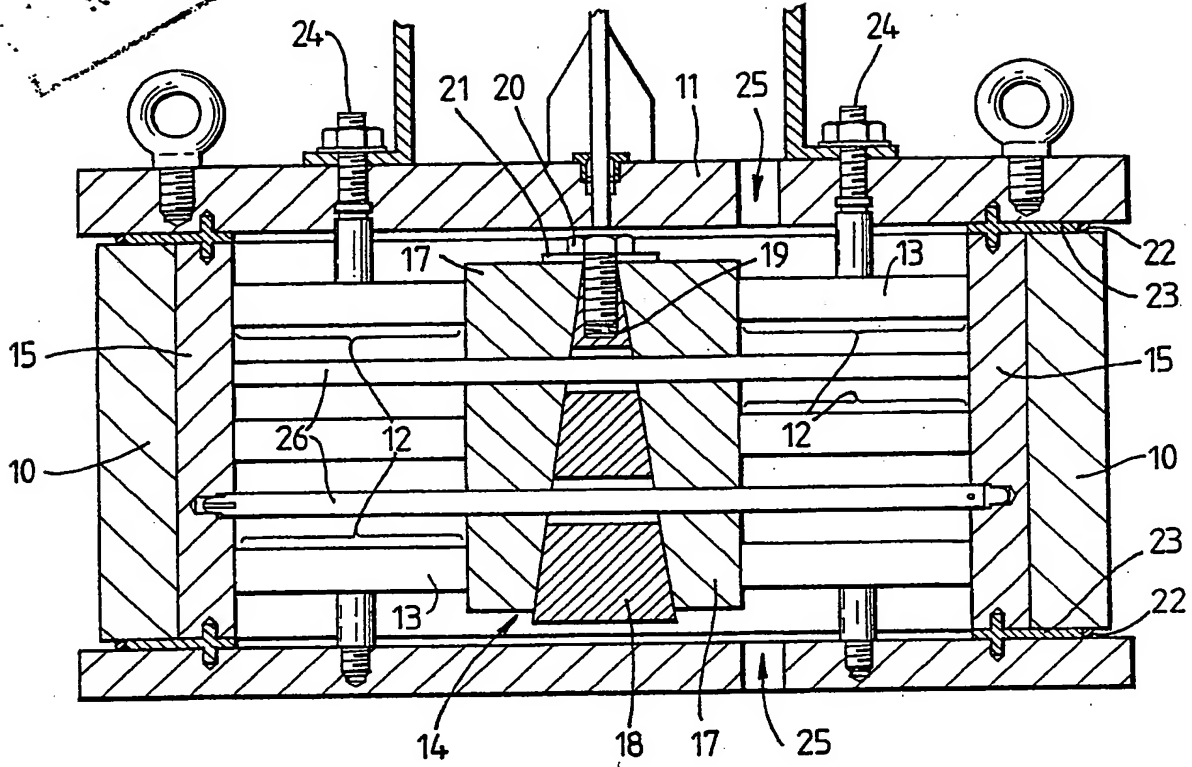
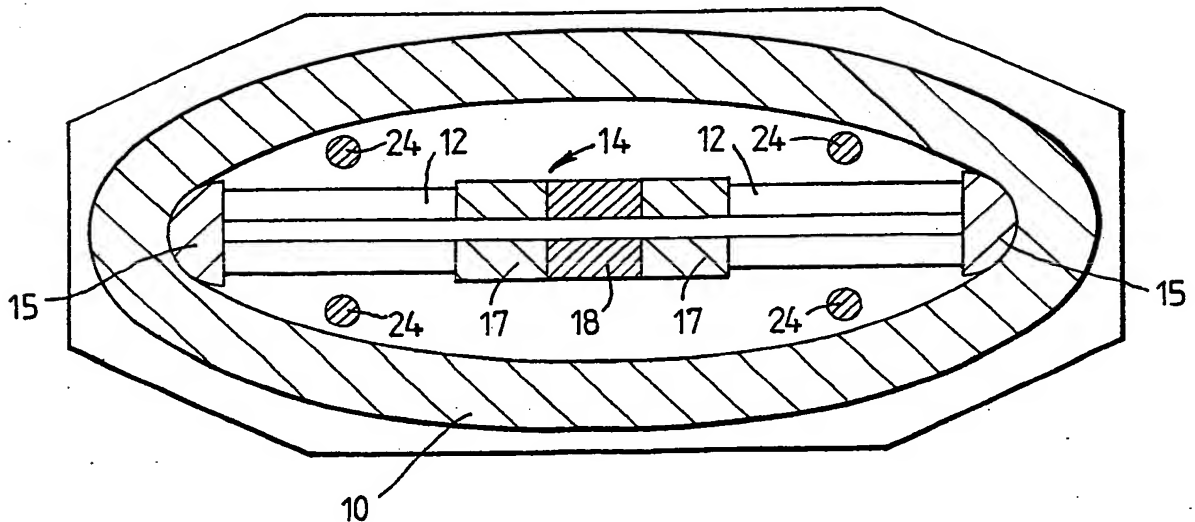


Fig. 3.



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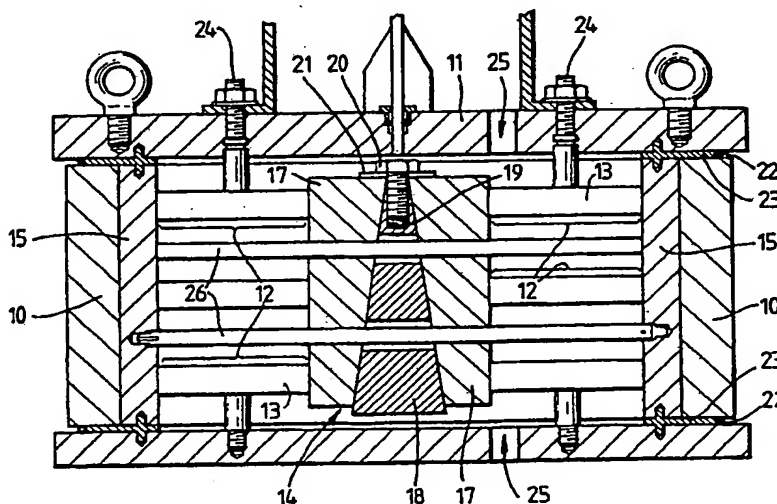
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Farnborough Hants GU14 6YU(GB)(54) **Flextensional transducers.**

(57) A flextensional transducer comprising a shell (10) defining a cavity and drive means (12) located in the cavity and adapted to cause the shell to flex and further comprising a Helmholtz resonator (10,

11, 25) for forming a hydrostatic pressure link and a low frequency acoustic link with the medium in which the flextensional transducer is located.

*Fig. 2.*



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